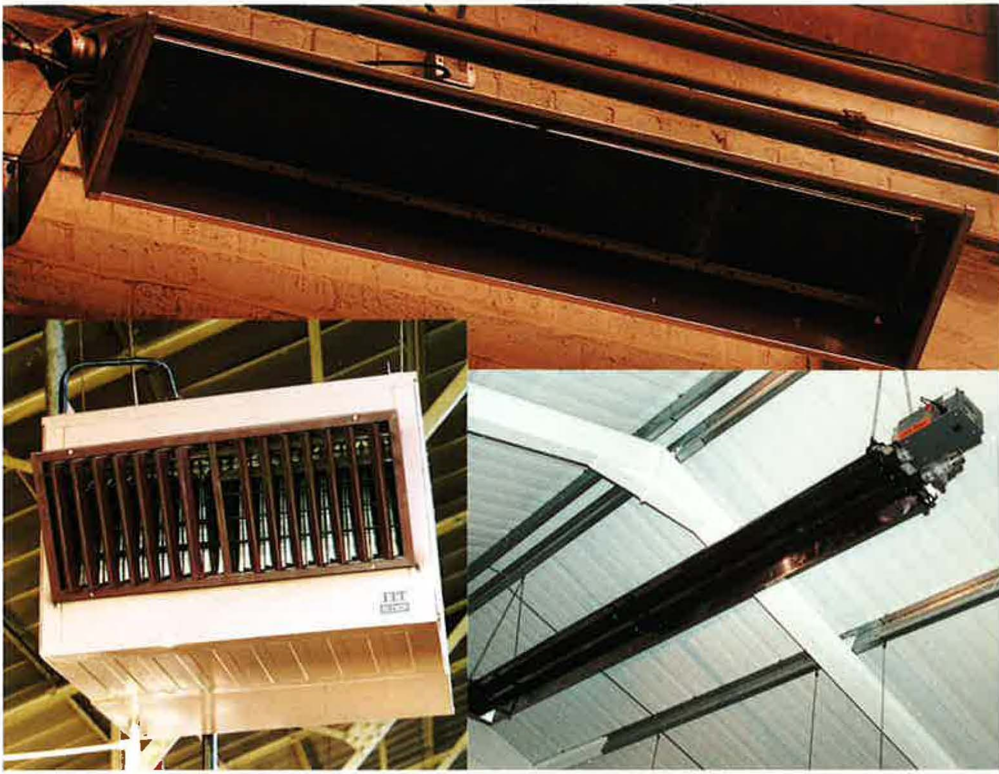
Economic Use of Fired Space Heaters for Industry and Commerce



Energy Efficiency Office
DEPARTMENT OF THE ENVIRONMENT

Economic use of fired space heaters for industry and commerce

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The views and judgements expressed in this Fuel Efficiency Booklet are not necessarily those of the Department of the Environment, the Energy Efficiency Office, ETSU or BRECSU.

Contents

1. Introduction

This booklet has been written to help those responsible for specifying and/or maintaining fired space heating systems within industry and commerce. It aims to give a better understanding of the factors involved to allow more energy efficient operation. This information should enable worthwhile savings in the running costs of most heating systems to be made.

Gas- and oil-fired heaters have played an increasingly important role in the heating of industrial and commercial premises over the last 20 years. These heaters are continually being developed and they have become considerably more compact and cheaper to run than the early models. Their selection, particularly for large volume applications such as shopping and warehouse areas, has become almost automatic. The main reasons for selecting this type of system are a low initial capital cost, ease of installation and economic operating costs.

Old or improperly operated systems can easily be using 10% more energy than ones which are correctly installed and maintained. Energy savings over the life of the system can easily pay for any additional expenditure on an energy efficient installation and a programme of planned maintenance.

One of the major advantages of fired heating systems is that they rapidly heat a building space with full output being given within seconds of being switched-on. This means that the heating need only operate for a short period before occupancy, usually a matter of minutes, thus heat losses during this period are minimised. Compared with some older types of radiator systems, where sometimes many hours of heating are required before occupancy, energy savings using fired heating systems can be as high as 50%.

2. Choosing the right type of heating

There are two main categories of fired space heater:

- warm air convection;
- radiant.

Within these categories there are a number of distinct types. Correct selection is important for comfort of personnel, product quality and installation and operating cost. This is determined by the duty required and the particular location of the heaters in the building.

In some applications it will be clear which type of heater is required, but in others there will be an overlap between one type and another. In these cases, consideration will have to be given to the structure and internal geometry of the building together with the type of work and any processes being carried out, the number and concentration of personnel, and the air change rates in the area to be heated.

All fired heaters consist of a combustion chamber or burner unit in which fuel and air are mixed and burned to give hot combustion gases. These gases are then cooled by heat transfer to warm the air within the building. The cooled combustion gases are finally exhausted from the heater unit via a flue system. The main differences between the various types of heater are in the means of heat transfer from the combustion gases.

2.1 Warm air convection heaters

Warm air convection heaters are at their most efficient when used in buildings that:

- are well insulated;
- have low ventilation rates.

Typically these may be general production areas in factories where the prime purpose is to provide a comfortable working environment, or warehouses and storage areas where the product has to be protected against frost or damp or needs to be stored in a fairly closely controlled temperature environment.

Preferably where only people are concerned, the buildings should have low ceilings, or low-bays, in order to reduce the volume of air to be heated. Where high ceilings, or high bays, are unavoidable resulting in warm air collecting near the roof, some form of destratification should be considered. This can either be by fans located near the roof, or by ducted air, sometimes as part of the heating system.

In all types of convection heater the air is raised in temperature before being blown, or directed via ducting, into the building. Different types of warm air heater either re-circulate air from within the building itself or take cooler fresh air from outside the building. In the latter case it is usually possible to combine fresh and re-circulated air in variable proportions, using adjustable dampers, to ensure the correct number of air changes per hour for the particular environment. (Table 2 (Page 5) gives typical air change rates for a variety of buildings.) A heater with a fresh air facility may have an additional advantage in summer in that it can be used to blow cooler air into the building thereby improving the environment and the working conditions.

Heat is distributed from a warm air convection heater by the use of a fan. In some types of heater the fan is variable speed with, say, a slow speed being used to maintain a set temperature level and a faster speed being used when the temperature requires boosting, for example at start up. When variable speed is combined with a high-low or modulating burner and/or sophisticated controls, the system becomes very flexible and can cater for many different types of working conditions and environments.

A possible problem with buildings that have been extensively draught proofed and have fresh air heaters is that they could become positively pressurised. If this occurs, exhaust ducts or vents will be required to reduce or eliminate the pressure build-up. In most cases, however, air leakage through the building structure will be sufficient, and when fresh air heaters are in use leakage will be from inside to outside which will help to eliminate any cold draughts.

Warm air heaters are available in many different sizes and shapes, covering a wide range of outputs. Often the choice can be between installing a large number of small units, or a small number of larger central units with distribution ducts. With low roofs the physical size of the ducting required might make the latter option impractical, whilst in other cases the aesthetic appearance of both heater and ducting might be a major consideration.

The following types of warm air heater are available. They are described in more detail in Appendix 1.

2.1.1 *Indirect fired warm air heaters*

In an indirect fired warm air heater a heat exchanger is used and the combustion gases and the air being heated are kept entirely separate. Indirect fired heaters have thermal efficiencies from 75% upwards, with the latest types of heat exchanger enabling efficiencies as high as 85% to be achieved.

2.1.2 *Direct fired warm air heaters*

A direct fired warm air heater does not have a heat exchanger. Air is heated by being mixed with hot combustion gases.

Without a heat exchanger even higher thermal efficiencies are possible. If the heater casing is within the space being heated then efficiencies close to 100% can be achieved. However it is necessary to provide fresh air to prevent combustion products from building up inside the building. This reduces the typical overall thermal efficiency to about 92%.

Other advantages of direct fired over indirect fired heaters are that lower rated fans can generally be used and, with no heat exchangers to foul, much less cleaning is required. Warm air heaters with unsilenced burners and powerful fans can, however, be very noisy and unsuitable for quiet environments.

2.1.3 *Condensing and pulse combustion heaters*

The efficiency of indirect fired heaters can be improved to as high as 96% by condensing the water vapour in the combustion products. This can be achieved using an additional heat exchanger which cools the exhaust gases to below 100°C. At such low temperatures draught from the flue is virtually non-existent so a positive means of exhaust, such as pulse combustion, has to be provided.

2.1.4 *High velocity distribution systems*

High velocity distribution systems consist of either a directly or indirectly fired air handling system, which heats air to a high temperature (100°C to 150°C) for distribution via ducting. The air is discharged downwards via nozzles which have the effect of entraining ambient air into the stream.

This type of system is suited to high bay areas as it reduces stratification (collection of warm air near the roof) and access to high level is not needed for routine maintenance.

This type of warm air system has a particular advantage over radiant heaters in cases where the building occupants are obscured from the radiant source, for example by having to work underneath a vehicle or an aircraft wing.

2.2 Radiant heaters

There are various types of radiant heaters on the market. These are generally gas-fired and in some designs the combustion products are discharged into the space being heated. If radiant heating can be used, it generally has the lowest capital cost and is the least expensive to operate. Radiant heat is a more effective means of heat transfer than heating the entire air volume of the building.

In contrast to warm air heaters, radiant heaters are advantageous where buildings:

- are poorly insulated;
- have high air-change rates;
- are high-bay;
- have high air volumes in relation to the people or objects to be heated;
- are only used intermittently.

They are also particularly useful when only a small part of a larger area requires heating. For example, if a few people work in the corner of a warehouse that otherwise needs very little heat, a radiant heater will provide spot heating where it is actually required. Another example would be a large factory or warehouse space converted into smaller individual areas using open topped partitions; an individual radiant heater can provide an efficient form of heating into a partitioned off area and, since it can be mounted at high level, no floor or wall space need be lost.

Whereas air heaters warm the air in order to warm the space, radiant heaters work by emitting infra-red radiation which only provides heat when it comes into contact with a solid object. This can be a person, table, wall, floor or any object in the room. The infra-red radiation is partially absorbed, thus warming the surface of the object, and partially reflected to hit another surface where the process continues. The net effect is that any person or object in the room, together with the walls and floor, warms up to the required comfort temperature. The air temperature also rises, but to the much lower level needed for comfort with radiant heating. For this reason radiant heaters are also suitable in buildings where high extraction rates are necessary, for example for the removal of fumes.

The following types of radiant heaters are available. They are described in more detail in Appendix 1.

2.2.1 *Radiant tube heaters*

When venting is directly into the workspace the overall efficiency of these heaters can be as high as 90%. The units are usually suspended from the ceiling, but well above head level to ensure radiation levels are not too high on the heads of occupants and more evenly distributed between the head and feet. When the units are direct fired, similar care has to be taken to that for direct fired warm air heaters, to ensure that the combustion products do not build up and that sufficient fresh air is being introduced into the building to give acceptable air quality standards for the occupants. Further information on ventilation rates can be found in the Health and Safety Executive publication HSE Guidance Note EH22 - 'Ventilation of the Workplace'.

2.2.2 *Radiant plaque heaters*

Radiant plaque heaters are direct fired by gas or LPG and operate by having a flame impinge on a ceramic plaque, which then glows red hot and radiates infra-red which in turn heats the building occupants as described previously. The surface temperature of the plaque is considerably higher than the black heat of a radiant tube heater, and so it emits a much higher proportion of radiant energy. Plaque heaters are therefore much more compact and can, if required, be mounted at a much greater height than the equivalent output radiant tube. Radiant plaque heater units cannot easily be vented and the same comments on introducing fresh air to the building apply as given for direct fired radiant tube heaters.

3. How much do the heaters cost to run?

The following hypothetical example in Table 1 shows how the annual running costs of indirect fired heaters, direct fired heaters, condensing heaters and radiant tube heaters are likely to differ in a well-insulated factory environment with a floor area of about 1,200 m^2 and an average floor to roof height of about 8 metres. The example is for single shift occupancy with all internal gains arising from a normal lighting load.

4. Keeping energy costs down

The cost of heating is minimised by reducing the various losses that are either associated with the design of the appliance or with the complete installation. The heat losses include the heat content of the flue gases. With a ducted heater when the appliance is not installed within the space to be heated, the radiation and convection losses from the casing itself must be included.

The thermal efficiency can be derived from the basic equation:

Heater thermal efficiency % =
100 - (%flue gas loss + % casing loss)

Table 1 Example of heater running costs

Type of heater	2 air changes per hour [1]		5 air changes per hour [1]	
	Annual running cost	**Capital cost**	**Annual running cost**	**Capital cost**
Indirect fired warm air	£8,000	£15,000	£16,000	£30,000
Direct fired warm air [2]	£6,500	£20,000	£13,000	£40,000
Condensing warm air [2]	£6,200	£20,000	£12,500	£40,000
Radiant tube [3]	£5,300	£15,000	£9,000	£30,000

Notes:

1 Typical air change rates for a variety of buildings are shown in Table 2 (Page 5).

2 The extra expense of direct and condensing warm air heaters is typically paid back within 3 years by their lower running costs.

3 Both the annual running cost and the capital cost of the radiant tube heating will, of course, be reduced if only part of the shop floor needs to be heated.

4 Installation of heaters at high level can sometimes be awkward. If extensive scaffolding is required this will increase the installation cost.

5 Continuous occupancy of the factory will approximately double the running costs while two shift occupancy will add about 66%. Internal gains also have a significant effect on running costs. Internal gains arise from the heat generated by lighting systems, people and equipment. If internal gains from the process are high it may be that the heating system is only used for pre-heating the building before occupancy in which case running costs will be down to about one third of figures shown in the table.

Keeping energy costs down also depends on effectively controlling the use of the heater both from a time and a temperature viewpoint. It also depends on operating and maintaining it correctly according to the manufacturer's instructions.

The various factors involved in keeping energy costs to a minimum are discussed in detail in the following sections:

- Section 4.1 - Installation considerations;
- Section 4.2 - Controls;
- Section 4.3 - Maintenance.

4.1 Installation Considerations

4.1.1 *Excessive ventilation of the heated space*

The air changes should be kept to the minimum required, bearing in mind any production processes, to give accepted air quality standards for the occupants. (See Section 5 for a list of publications which give guidance on ventilation levels.) If high rates of air change are required, fuel savings may be made by using radiant heaters to maintain comfort levels in occupied areas.

With direct firing air heaters, thermal efficiency is high (see Section 2). However, as the combustion products are mixed with the air to be heated, greater than normal rates of air change may be required to carry away water vapour, which would otherwise give rise to unwanted condensation within the heated space, and also to maintain acceptable air quality standards. BS 6230: 1991 specifies a maximum limit of 0.28% carbon dioxide in the heated space. An increased ventilation rate may result in more air being heated and therefore more fuel being used.

The economics of this type of system should therefore be calculated carefully for each individual application, taking into account air change rates, before system selection is made.

The number of air changes per hour normally found or required is listed in Table 2.

4.1.2 *Radiation/convection losses from the heater casing*

Where possible warm air heaters should be installed within the space being heated as this captures the heat which would otherwise be lost by radiation and convection from the heater casing. This loss can amount to 1 or 2% of the fuel used if the heater is located in an external plant room or other location where heating is not required.

4.1.3 *Losses from air heater ducting*

If hot air is ducted through areas not intended to be heated, any heat emission from these ducts represents a loss in effective thermal efficiency. This loss can be minimised by the application of insulation to the duct surfaces. (See Fuel Efficiency Booklet No. 8 - 'The economic thickness of insulation for hot pipes').

4.1.4 *Circulating fan at roof level*

The warmest place in any enclosed space is normally just below the roof, and in a factory, for example, the temperature at roof level may be 10°C or more above that needed by the occupants at floor level. A proportion of the fuel heat therefore goes to heating air that resides wastefully at a high level, giving rise to increased rates of heat loss through the roof.

The situation can be improved by the installation of one or more de-stratification fans at roof level, designed to transfer the hot air to the working area where it is needed. In general this type of fan is thermostatically controlled and operates only when there is a build-up of hot air at high level. However, the use of circulating fans may not always be desirable where, for example, roof

Table 2 Typical number of air changes required

Building Type	Number of air changes per hour
Large factory	0.5
Small factory	1.0
Warehouse	0.25
Goods Inward/Despatch	Up to 5.0
Offices	1.0

mounted extract fans are installed to exhaust odours and fumes arising from production processes to the outside air. In these situations it is usually advantageous to use radiant heaters.

4.1.5 *Automatic flue dampers*

Automatic flue dampers are intended to prevent the escape of heat from the flue gas space to the chimney during the time that the burner is idle. Potential savings are greatest when there is rapid burner cycling and/or there is a high chimney draught.

There must always be full electrical interlocking between the shut-off damper and the burner to ensure that the burner cannot start while the damper is closed. Manually adjusted shut-off dampers must not be used.

4.2 Control

Sophisticated controls are available which can reduce the running costs of the various heaters. Control functions which should be considered are:

4.2.1 *Time control*

Switching heaters off when the building is unoccupied is an obvious energy saving measure and can be done automatically using a time clock. As fired heating systems respond quickly, the clock can usually be set to switch on the heating a few minutes before occupancy.

4.2.2 *Optimum start control*

In situations where the building takes a long time to warm up, for example, large volume or heavy masonry construction, optimum start may be of value. Optimum start control varies the time at which the heating system is switched on depending on the temperature inside and outside of the building.

4.2.3 *Modulating rather than on/off controls*

Control of space temperature is normally achieved by switching the burner on and off according to a thermostat which measures space temperature (either wall mounted in the space or in the space air intake of the heater). With larger heaters, this type of control can lead to some discomfort as one moment the heater is giving full output and the next no output at all. This can lead to energy being wasted as thermostats settings are raised to pacify complainants. This problem can be avoided by using a high/low fire burner which has an intermediate heat output level to smooth temperature control. An even better solution is to use a modulating burner which is continuously controlled to give the heat output required for the building.

4.2.4 *Setback temperature control*

Some electronic thermostats are able to control at selected temperatures depending on the state of occupancy. Personnel detectors can be used to detect periods of non-occupancy during the normally occupied period and reduce the temperature setpoint by up to 5°C. Warm air and radiant heating systems respond quickly, so comfort conditions can rapidly be regained when normal occupancy resumes.

4.2.5 *Building fabric protection*

During out of hours periods, a low thermostat setting should be used to keep temperatures at the minimum required for building fabric and services protection.

4.2.6 *Controls for radiant systems*

Controls have been developed which use a combination of dry bulb and black body temperatures to maintain a comfortable temperature.

4.2.7 *Building Energy Management Systems*

Multiple heater installations can be controlled by a Building Energy Management System, which can incorporate all of the above control functions as appropriate, as well as reporting alarms and fuel usage if required.

4.2.8 *Positioning of thermostats*

If the temperature of the heated space is controlled by a thermostat, this should be positioned so that it is fully responsive to the temperature of the relevant area, otherwise higher than necessary temperatures may be maintained with a consequent increase in energy costs. The thermostat for floor standing heaters and for warm air heaters in low bay areas can be located

inside the heater in the space air intake. This gives a good average temperature for the area being served. It is, however, necessary to ensure that other control functions (such as low temperature cut-out) do not stop the fan within the heater or else the thermostat will merely sense the temperature within the heater casing.

4.2.9 Control settings

A statutory requirement is that space heating should cease when the temperature exceeds 19°C[1]

A further statutory requirement is that the work place should be up to 16°C one hour after occupancy[2]. Setting of time controls need to take this into account.

The Fuel and Electricity (Heating) (Control) (Amendments) order 1980 SI 1980, No 1013, prohibits the heating of public, commercial, and industrial premises to a temperature exceeding 19°C.

4.3 Maintenance

Continued high operating efficiency of any space heating system requires regular maintenance. In the case of fired space heaters, this should be carried out annually either by qualified maintenance staff or by a specialist maintenance contractor.

The maintenance procedures required are listed below. These are described in more detail in Appendix 2.

- Measurement of flue gas losses
- Burner adjustment
- Restricted air flow through the heater
- Dirty heat transfer surfaces
- Damaged flue gas baffles or retarders
- Leakage of hot air
- Dirty metallic reflectors fitted to radiant heaters

By installing, operating and maintaining a heater in accordance with the instructions supplied with it, the resulting thermal efficiency should be close to that stated by the manufacturers. Conversely, not following the instructions can reduce the efficiency by a number of percentage points.

Installed heaters should be inspected and tested on a regular basis, to ensure that any drift from the optimum efficiency is identified and rectified. This will eliminate prolonged operating periods with higher than necessary fuel costs. Manufacturers' instructions generally recommend annual inspection, although it will often be beneficial for works' personnel to record flue gas losses at more regular intervals initially, to establish a suitable frequency for checking particular installations.

Specialist maintenance contractors can be identified through local trade directories or by recommendation from equipment suppliers. Upon installation of new equipment it is usually possible to negotiate maintenance contracts with equipment suppliers.

A specialist maintenance contractor should be able to demonstrate that he has the necessary combustion efficiency measuring equipment and should provide a simple report of the tests undertaken as well as a check list of other items inspected. Any adjustments, replacement parts or other recommended action should be included in the report. It should be possible to identify any problems with the space heating system by recording fuel bills and checking them against bills for similar periods in previous years. This is the simplest form of energy monitoring. This can be done more effectively by taking into account other factors which effect energy consumption of heating systems such as outside temperatures and shift patterns. See reference section for information sources on energy monitoring.

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1 Lockable thermostats or remotely sited controls should be used to avoid unauthorised re-setting.

2 Factories Act 1961 and Offices, Shops and Railway Premises Act 1963.

5. Sources of further information

This section lists publications and information sources which may be of relevance to those responsible for the economic use of fired space heating. The list is not exhaustive and is intended for guidance only.

- ***British Standards:***

BS 6230: 1991 -	Specification for installation of gas fired forced convection air heaters for commercial and industrial space heating (2nd family gases).
BS 4256: Part 2 -	Specification for oil burning air heaters. Fixed, flued, fan assisted heaters.
BS 5410: Part 2: 1978 -	Code of Practice for oil firing. Installations of 44 kW and above output capacity for space heating, hot water and steam supply purposes.
BS 5720: 1979 -	Code of Practice for mechanical ventilation and air conditioning in buildings.
BS 5925: 1980 -	Code of Practice for design of buildings: ventilation principles and designing for natural ventilation.

- ***Health and Safety Executive:***

HSE Guidance Note EH22 - Ventilation of the Workplace.

- ***EEO Publications:***

Good Practice Guide 61 - Design Manual. Energy Efficiency in Advance Factory Units.

GPG 62 - Occupiers Manual. Energy Efficiency in Advance Factory Units.

Copies of the above publications and other literature applicable to energy efficiency in buildings are available from:

Enquiries Bureau
BRECSU (Building Research Energy Conservation Support Unit)
Building Research Establishment
Garston
Watford WD2 7JR
Tel No: 01923 664258 Fax No: 01923 664787

Energy Containing the Costs

You've Got the Power - Saving Money by Saving Energy (Audio Cassette and booklet)

Monitoring and Targeting (Video Cassette)

Copies of the above publications and other literature applicable to energy efficiency in industry are available from:

Energy Efficiency Enquiries Bureau
ETSU
Harwell
Oxon OX11 0RA
Tel No: 01235 436747 Fax No: 01235 432923

Information is also available through Regional Energy Efficiency Offices (REEOs).

- ***Best Practice programme events:***

BRECSU and ETSU run events to promote the Best Practice programme and energy efficiency on behalf of the Energy Efficiency Office. Details of events can be found in 'Energy Management' (see below).

- ***HVCA Standard Maintenance Specification for Mechanical Services in Buildings:***

The following publications were prepared jointly with the EEO under the Best Practice programme.

I	Heating and Pipework Systems
II	Ventilating and Air Conditioning
III	Control, Energy and Building Management Systems
IV	Ancillaries, Plumbing and Sewerage Systems
V	Electrics in Buildings

Copies of these publications are available from:

HVCA Publications
Old Mansion House
Earmont Bridge
Cumbria
CA10 2BX
Tel No: 01768 64771

- ***The latest news in energy efficiency technology***

'Energy Management' is a free journal issued on behalf of the EEO which contains information on the latest developments in energy efficiency, and details of forthcoming events to promote their implementation. It also contains information, addresses and contact names for the Regional Energy Efficiency Offices (REEOs).

Copies of 'Energy Management' can be obtained through:

Energy Management Journal
Emap Maclaren House
18 Scarbrook Rd
Croydon
Surrey
CR9 1QH

Appendix 1

Heater types

A1.1 Indirect fired warm air heaters

In an indirect fired warm air heater a heat exchanger is used and the combustion gases and the air being heated are kept separate.

Floor standing heaters are available with rated outputs typically in the range 30 to 440 kW, while suspended heaters range from 10 to 120 kW. This type of heater is illustrated in Fig 1.

Although hot air is discharged directly into the space to be heated from the majority of heaters, models can also be supplied as ducted heaters.

Indirect fired heaters require an air intake, which can be either fresh or room air, and a flue to take the combustion products out of the building. These heaters can therefore run on a wide range of fuels including gas, oil, and LPG.

Recent developments include heaters fitted with low NOx burners which reduce the environmental impact of the flue gases.

Indirect fired heaters have thermal efficiencies from 75% upwards, with the latest types of heat exchanger enabling efficiencies as high as 85% to be achieved.

A1.2 Direct fired warm air heaters

In a direct fired warm air heater the heat exchanger is removed and heat transfer is effected by mixing the hot combustion gases with the air being heated.

Without a heat exchanger even higher thermal efficiencies are possible. If the heater casing is within the space being heated then efficiencies close to 100% on a net calorific value basis can be achieved. The fuel is burned in the main air flow through the heater, and the combustion products are mixed into the total air volume and distributed throughout the building. The need for a flue is eliminated but only the purer types of fuel, such as natural gas and LPG which produce mainly carbon dioxide and water vapour, can be used.

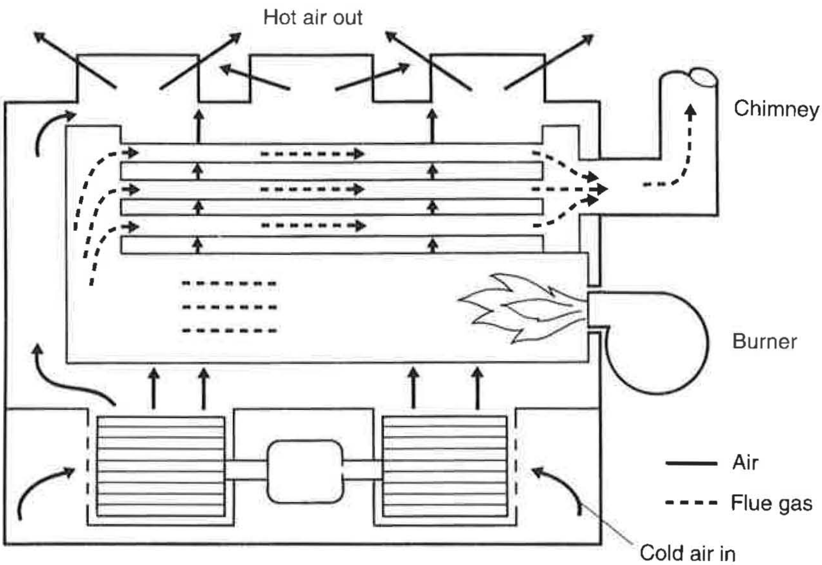


Fig 1 Indirect fired air heater

Typical heat outputs are in the range 30 to 400 kW, and the type of heater is shown in Fig 2.

A large quantity of excess air is required to ensure carbon monoxide is not formed, and this also brings the delivered air down to a reasonable temperature. Care must be taken to ensure that the combustion products do not build up and that the water vapour does not result in unacceptable humidity levels. Sufficient fresh air must be introduced into the building to give an acceptable air quality standard for the occupants. The amount of fresh air required will depend on the number, size, distribution and firing times of the heaters. Consideration must also be given to any other processes taking place in the building that give off combustion products, unacceptable fumes or vapours and, particularly, flammable vapours.

The necessary provision of at least a proportion of fresh air means that there is effectively a low temperature discharge of the combustion products from the building, and this is equivalent to a small flue loss. Typical overall thermal efficiency, therefore, would be of the order of 92% based on the gross calorific value of the fuel, which is still higher than that of indirect fired heaters.

Other advantages of direct fired over indirect fired heaters are that lower rated fans can generally be used and, with no heat exchangers to foul, much less cleaning is required. Warm air heaters with unsilenced burners and powerful fans can, however, be very noisy and unsuitable for quiet environments.

A1.3 Condensing and pulse combustion heaters

The efficiency of indirect fired heaters can be improved to as high as 96% by condensing the water vapour in the combustion products. This can be achieved using an additional heat exchanger which cools the exhaust gases to below 100°C. At such low temperatures draught from the flue is virtually non-existent and a positive means of exhaust has to be provided. One proprietary product utilises the pressure pulse from intermittent combustion to discharge the exhaust products, and these are known as pulse combustion devices.

Pulse combustion units are available for heat outputs in the range 11 to 28 kW. Other more conventional condensing heaters are available in the range 14 to 59 kW and are illustrated in Fig 3.

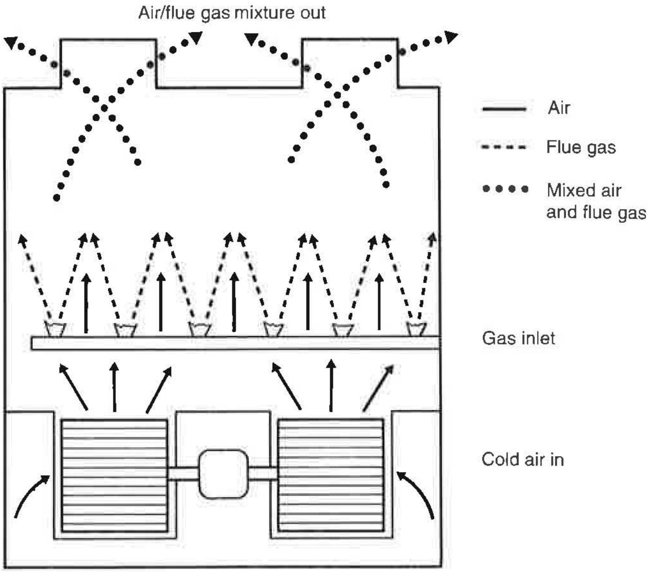


Fig 2 Direct fired air heater

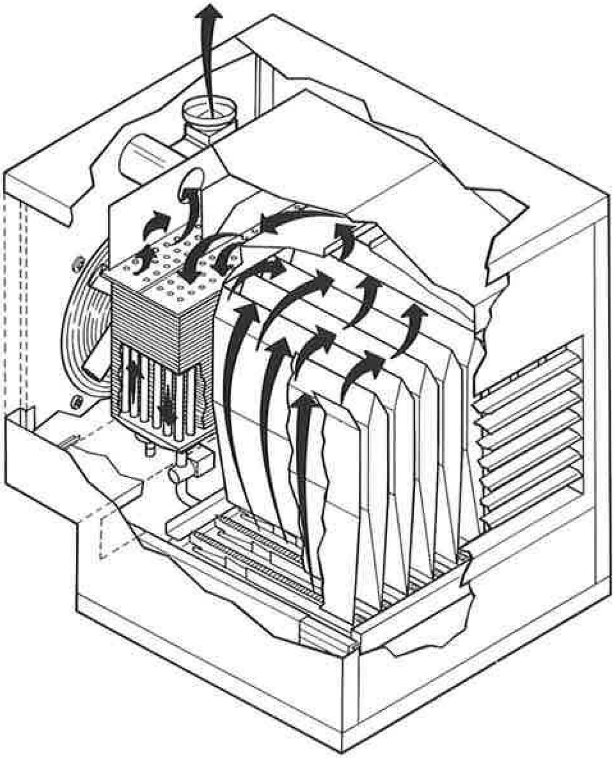


Fig 3 Condensing warm air heater

A1.4 High velocity distribution systems

High velocity distribution systems consist of either a directly or indirectly fired air handling system, which heats air to a high temperature (100°C to 150°C) for distribution via ducting. The air is discharged downwards via nozzles which have the effect of entraining ambient air into the stream.

This type of system is suited to high bay areas as it reduces stratification (collection of warm air near the roof) and access to high level is not needed for routine maintenance. Fig 4 shows one of these systems.

This type of warm air system has a particular advantage over radiant heaters in cases where the building occupants are obscured from the radiant source, for example by having to work underneath a vehicle or an aircraft wing.

A1.5 Radiant tube heaters

In radiant tube heaters, heat transfer is by radiation.

Radiant tube heaters are generally gas- or LPG-fired. Some discharge their combustion products into the space to be heated and are therefore classed as direct fired units. Heat inputs are generally in the range 10 to 60 kW. Fig 5 shows a typical arrangement for a radiant tube heater.

The burner is mounted at one end of a U tube which is enclosed within a stainless steel reflector, designed to ensure the unit radiates its heat down to the ground and not up into the ceiling. Using a vacuum fan, the hot combustion products are sucked along the tube before being vented to atmosphere. When venting is directly into the workspace the overall efficiency of these

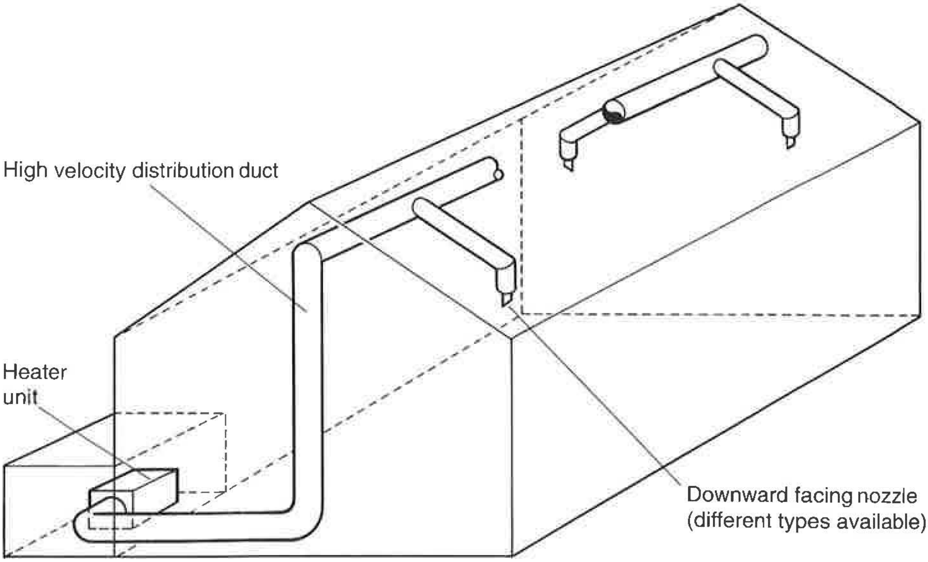


Fig 4 High velocity hot air distribution

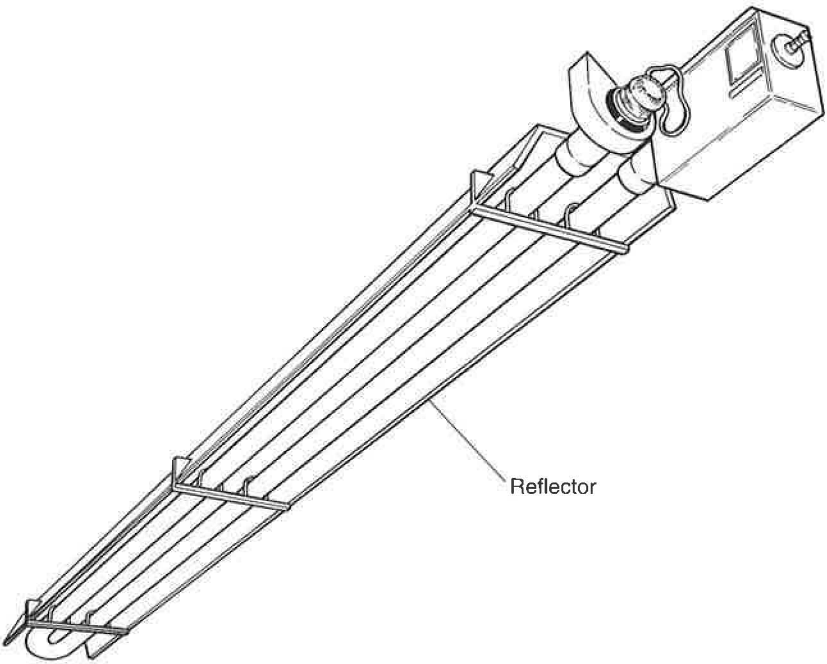


Fig 5 Radiant tube heater

heaters can be as high as 90%. The units are usually suspended from the ceiling, but well above head level to ensure radiation levels are not too high on the heads of occupants and more evenly distributed between the head and feet. Modulated instead of on/off control can be used to help prevent high radiation levels on the head.

Variations on the basic design include a long single tube with a burner at one end and an extractor fan at the other, or a very long tube or series of tubes with a number of burners where each burner boosts the temperature of the internal gases as they are sucked along the tube.

The fans and burners generate some noise and so may not be suitable for very quiet environments.

When the units are direct fired, similar care has to be taken to that for direct fired warm air heaters, to ensure that the combustion products do not build up and that sufficient fresh air is being introduced into the building to give acceptable air quality standards for the occupants.

A1.6 Radiant plaque heaters

Radiant plaque heaters are direct fired by gas or LPG and operate by having a flame impinge on a ceramic plaque, which then glows red hot and radiates infra-red heat.

Heat inputs are generally in the range 3 to 30 kW. Fig 6 shows a typical arrangement for a plaque heater.

The surface temperature of the plaque is considerably higher than the black heat of a radiant tube heater, and so it emits a much higher proportion of radiant energy. Plaque heaters are therefore much more compact and can, if required, be mounted at a much greater height than the equivalent output radiant tube. The open flame can, however, produce a combustion roar which might be unacceptable in some applications. Radiant plaque heater units cannot easily be vented and the same comments on introducing fresh air to the building apply as given for direct fired radiant tube heaters.

A specialised form of plaque heater uses a heated catalyst impregnated surface. The gas or LPG oxidises without flame giving 100% combustion, with only water vapour and carbon dioxide as combustion products. Although mainly used in production processes where they can be used in the presence of flammable vapours, these heaters can be useful in space heating applications where ventilation is restricted.

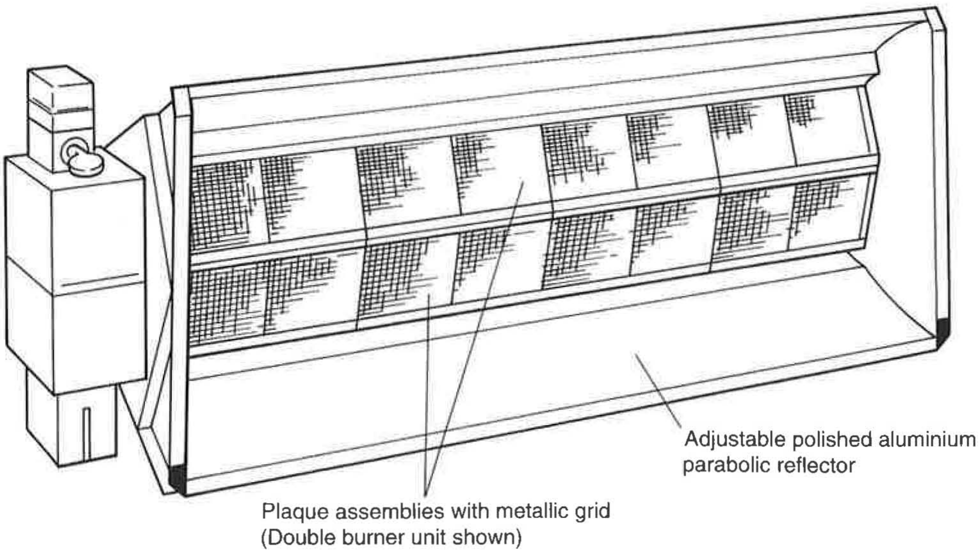


Fig 6 Radiant plaque heater

Appendix 2

Maintenance Procedures

A2.1 Measurement of flue gas losses

Measurement of flue gas losses is generally carried out on an annual basis as part of the maintenance procedure defined by the heater manufacturer. However it may be useful to check the combustion performance more frequently in order to correct any drift away from the optimum settings.

To check that the air/fuel ratio complies with the manufacturer's recommendations, the usual method is to measure the $\%O_2$ (or $\%CO_2$) in the flue gases at the heater exit. The flue gas temperature should be measured at the same position. By using these data together with charts similar to those shown in Figs 7 and 8, the % flue gas loss can be derived. The sampling point used should be that recommended by the heater manufacturer in order that a valid comparison can be made between the design and measured conditions.

When measuring flue gas losses, the following points should be considered:

- Before measurements are recorded, the heater should be operated continuously at a fixed firing rate for a stabilising period of at least 15 minutes (use the heater manufacturer's recommended setting and time period).
- Care should be taken to ensure the measuring instruments are operated according to the manufacturer's instructions, are correctly serviced and are operating with the accuracy claimed for them.
- Sampling probes should be inserted to the same depth within the flue gas duct used for previous readings, to ensure correct comparison. Relatively inexpensive portable instruments are available which, by sampling the flue gases through an integral probe, measure the flue gas constituents (generally $\%O_2$) and temperature. These values together with the computed combustion efficiency will appear on a digital display within about a minute.
- The flue gas samples should not be diluted by air inleakage before the sampling point, for example through joints, as this will give misleading results.

Oil-fired heaters should be checked for smoky combustion by either visual inspection of the flue exhaust or by smoke spot test using a sampling pump and filter paper. The Smoke Number on the Bacharach Scale should not exceed 0 - 1 during continuous burner operation. If this cannot be achieved at the manufacturer's recommended $\%O_2$ or $\%CO_2$ setting, the combustion system should be investigated further.

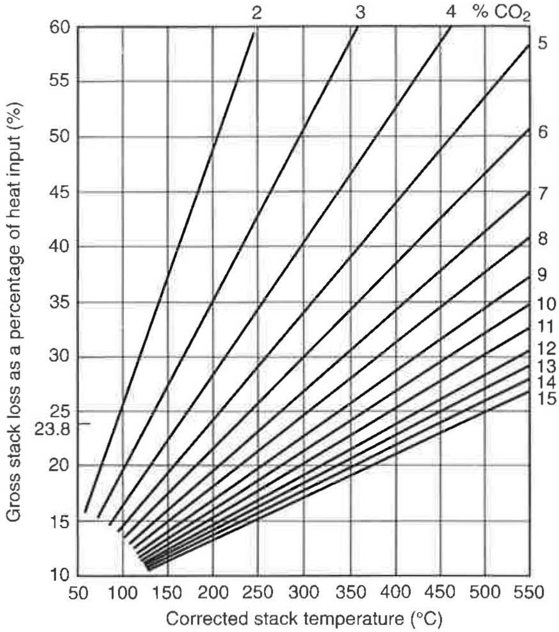
A2.2 Burner adjustment

A2.2.1 *Forced draught burners and indirect fired heaters*

To achieve a high thermal efficiency, the amount of combustion air should be limited to that necessary to ensure complete combustion of the fuel at all times. The optimum air/fuel ratio for the heater/burner combination is determined by the design. This setting has to satisfy the range of conditions likely to be met in different installations over perhaps months of uninspected operation.

If too much combustion air is supplied, as indicated by a high percentage oxygen in the flue gases, some fuel heat will be used merely to raise the temperature of this air from ambient to flue gas temperature, before discharging it to the chimney. (See Section A2.1 on the measurement of flue gas losses).

Conversely, if too little combustion air is supplied, some fuel may remain unburned, and in some circumstances soot may be deposited on heat transfer surfaces thereby increasing running costs. Additionally, insufficient combustion air will produce long flames which can damage the heater combustion chamber, the flue gas carbon monoxide content may be excessive and, with oil burning, there may be emission of visible smoke. If the latter is excessive it may contravene the Clean Air Act.



Corrected stack temperature = measured stack temperature + (15°C — measured ambient temperature)

Fig 7 Stack loss chart (gross) - Class D fuel (gas oil)

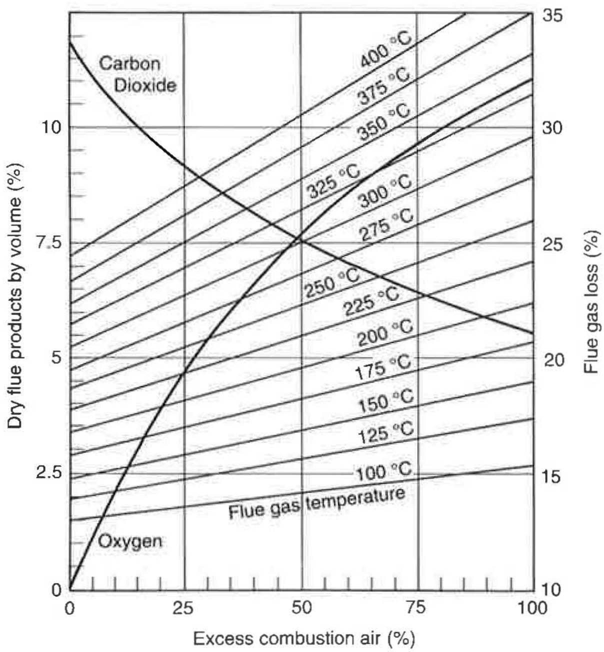


Fig 8 Flue gas losses (gross) - natural gas

It is normal practice for air heater burners to operate only at a firing rate corresponding to the heater's rated output. Some larger designs have two-stage operation, giving a reduced firing rate during start-up to minimise the sudden rise in combustion chamber pressure caused by the initiation of combustion. This low firing rate is of short duration and has little effect on the overall thermal efficiency of the heater.

However, if designs incorporate High/Low or modulating burners intended to match the input rate more closely to the heat load, then in order to reduce costs, the optimum air/fuel ratio should be chosen for each firing rate. Recommended values will be given by the heater manufacturer, but incorrect adjustment or wear on cams and linkages in the burner can result in settings that give a loss of efficiency. Servicing should generally be carried out annually to avoid this problem. If, after reference to the manufacturer's operating instructions, the recommended values cannot be achieved, the manufacturer's advice should be sought.

A2.2.2 *Natural draught or atmospheric gas burners and indirect fired heaters*

At the heater design stage, gas injectors and pressures are selected to induce the correct volume of combustion air into the heater. From the point of view of thermal efficiency, the only checks to be carried out on the combustion system of an installed heater are to ensure that the gas pressure is set to that recommended by the heater manufacturer and that the burner is clean.

A2.3 Restricted air flow through the heater

If the volume of air passing through the heater is less than that intended by the manufacturer, the delivered air temperature will rise. This results in increased flue gas and casing temperature, and reduced thermal efficiency. If the air temperature rises and exceeds the high temperature thermostat setting, the burner will cut out. If, however, this limiting temperature is not reached, the heater may continue to operate for lengthy periods with a higher than necessary flue gas loss.

Restricted air flow can be caused by:

- excessive discharge and return duct resistance;
- partially blocked air filters;
- the positioning of items close to the air discharge or inlet;
- incorrect speed of the air circulating fan;
- dirt on the blades of the air circulating fan.

A2.4 Dirty heat transfer surfaces

The accumulation of deposits within the heater will reduce the rate of heat transfer to the air stream and consequently will result in higher than normal flue gas losses. Cleaning costs will quickly be repaid by the resulting fuel saving. Cleaning should usually be carried out on an annual basis, although the heater manufacturer's recommendations on intervals between servicing should be followed.

A2.5 Damaged flue gas baffles or retarders

Baffles or retarders are often included in the design of air heaters to increase flue gas turbulence. This helps to reduce fouling of the heat transfer surfaces. Any baffles or retarders which are fitted should be inspected during servicing to ensure that they are still functioning correctly. If there are any signs of damage they should be repaired or replaced, otherwise the flue gases will be able to short-circuit these devices.

A2.6 Leakage of hot air

During servicing, joints in the heater should be examined to ensure that they are still airtight, to prevent the escape of heated air into the flue gas passages. Any seams and joints in ducting should also be examined.

A2.7 Dirty metallic reflectors fitted to radiant heaters

The effectiveness of tubular radiant heaters is enhanced by reflection of heat from the top surface of the heated tubes. An inefficient reflector can result in a greater than normal amount of heat remaining at a high level, increasing the overall losses. Reflectors should be examined during servicing for any discolouration that could impair their performance. The heater manufacturer's advice should be sought on suitable cleaning materials that avoid damage to the reflective surface.

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